4.0 PRIOR STUDIES, REPORTS AND EXISTING WATER PROJECTS

Initial alternatives were developed for this project as part of a 2-day "Cartersville Diversion Dam Project Study" conducted February 25-26, 2009. The purpose of the study was to expand the existing list of project alternatives and prioritize them. Agencies and stakeholders represented at this 2-day meeting included:

- U.S. Fish and Wildlife Service (USFWS)
- U.S. Army Corps of Engineers (USACE)
- Montana Department of Fish, Wildlife, and Parks (FWP)
- Montana Department of Environmental Quality (DEQ)
- Natural Resource Conservation Service (NRCS)
- Yellowstone River Conservation District
- Cartersville Irrigation District
- Nature Conservancy

Through this process, the participants generated 60 ideas for various alternatives. Of these, seven were selected for further development.

4.1 Controlled Notch in Crest of Dam Controlled by Inflatable Bladder

This alternative would utilize the existing dam with the modification of constructing a 200-foot (ft) long notch in the crest of the dam (Figure 4-1). The notch would be about 3-ft deep measured from the crest, to allow fish to pass. A 1-ft high roller compacted soil cement type of apron would be constructed on the downstream side of the notch to control flow velocity and stabilize the river bed.

A 3-ft high rubber bladder dam would be installed on the downstream edge of the notch. It would remain deflated for most of the year and inflated only when needed, typically in August and September to provide head to divert water into the slough.

The bladder would only be inflated during periods of very low flow below 4,000 – 5,000 cubic feet per second (cfs). Fish passage could still be provided for about 2 hours a day by utilizing the storage capacity of the slough.

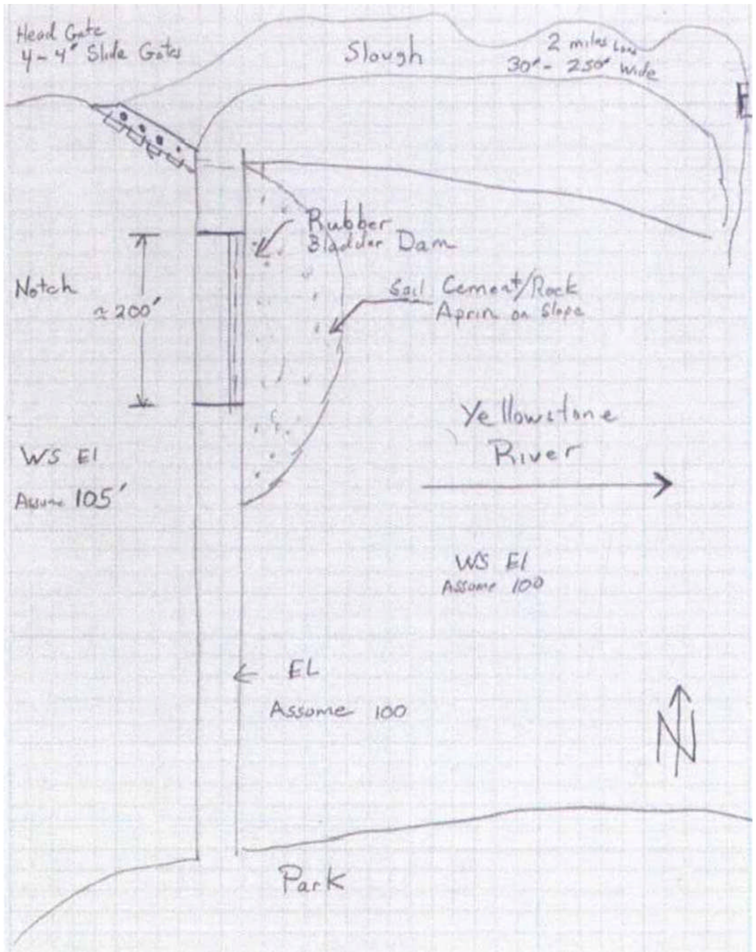

Figure 4-1 Inflatable Dam, February 2009

While the dam is raised, the slough would be filled to capacity, at which time the headgates could be shut and the dam lowered to provide fish passage for a short period of time while canal diversions continue from the slough. When the slough elevation drops too low for adequate canal diversion, the bladder dam would be raised and diversion into the slough would resume.

<u>Advantages</u>:

- Dam remains mostly intact; community acceptance
- Allows fish passage most of the year – especially in spring and fall
- Provides head to divert water at current elevation of dam crest
- Does not create potential for increased flood risk upstream
- Increased safety could be incorporated

This alternative was dismissed from further consideration due to the following:

- Notch near headgate may increase entrainment
- Possible bank erosion downstream
- Damage from trees, ice, debris, boats, and potential vandalism may necessitate periodic bladder replacement

4.2 Engineered Fishway Around South Abutment of Existing Dam

A rock channel fishway with boulder weirs would be constructed around the south abutment of the existing dam (Figures 4-2 and 4-3). The channel would have 8-ft bottom with 2:1 side slopes, and a top width of 24-ft. To achieve a 4-ft height, a 200-ft channel would be at 2% slope, which is the maximum recommended to pass native fish in the Yellowstone River. The entrance would be just below the existing dam on the south side, and just upstream of the existing boat ramp. Boulder weirs would be used to baffle velocities; 10 weirs spaced every 20-ft would be recommended. The upstream exit of the fishway would tie into the existing side channel of the Yellowstone River. Based on rough estimation compared to a similar proposal at Intake Diversion Dam near Glendive, Montana, an 8-ft bottom fishway would convey 1-5% of the flow of the river.

Advantages:

- Simple, inexpensive to implement
- Contained on State Property
- Side channel would alleviate concerns with ice damage to engineered structures
- Keeps dam intact for social and historic considerations
- Possible enhancement of recreational boat passage

This alternative was dismissed from further consideration due to the following:

- Attraction flows may not be adequate to efficiently pass all species of fish.
- Dam would need to be stabilized – future maintenance without stabilization would likely consist of continued addition of rock that could move downstream and interfere with the proper function of the fishway.
- Relies on continued flow in the side channel to provide fishway flow – if the side channel deactivates in the future the fishway would not function.
- Possible impacts to the campground / recreation area.

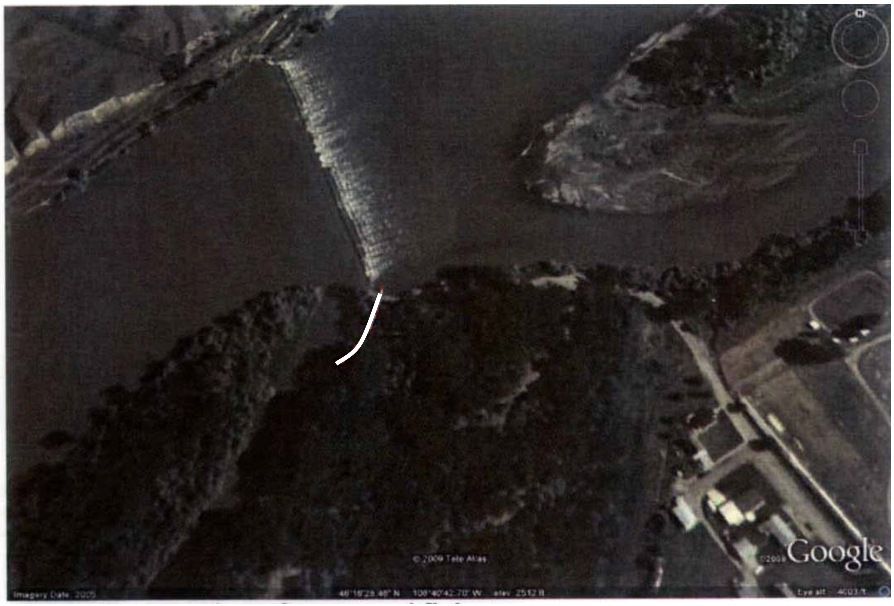

Figure 4-2 Location of Proposed Fishway

Figure 4-3 Muggli Fishway on the Tongue River (similar to proposed)

4.3 Partial Diversion Dam

This alternative would replace the existing diversion structure with a partial span diversion dam, creating a relatively natural gradient open channel on the southern side of the river (Figure 4-4). A physical model investigation would be needed to ensure optimization of water delivery and fish passage requirements and determine structure configuration and length. For conceptual purposes, a half to three-quarter span straight structure constructed of sheet pile was considered. Pile cells would be filled with native cobble and capped with concrete. Riprap would be added up and downstream of the sheet pile and at open end of structure for reinforcement. Structure would be designed for no operation and maintenance (O&M) for 30 years but will require addition of riprap downstream periodically in the future.

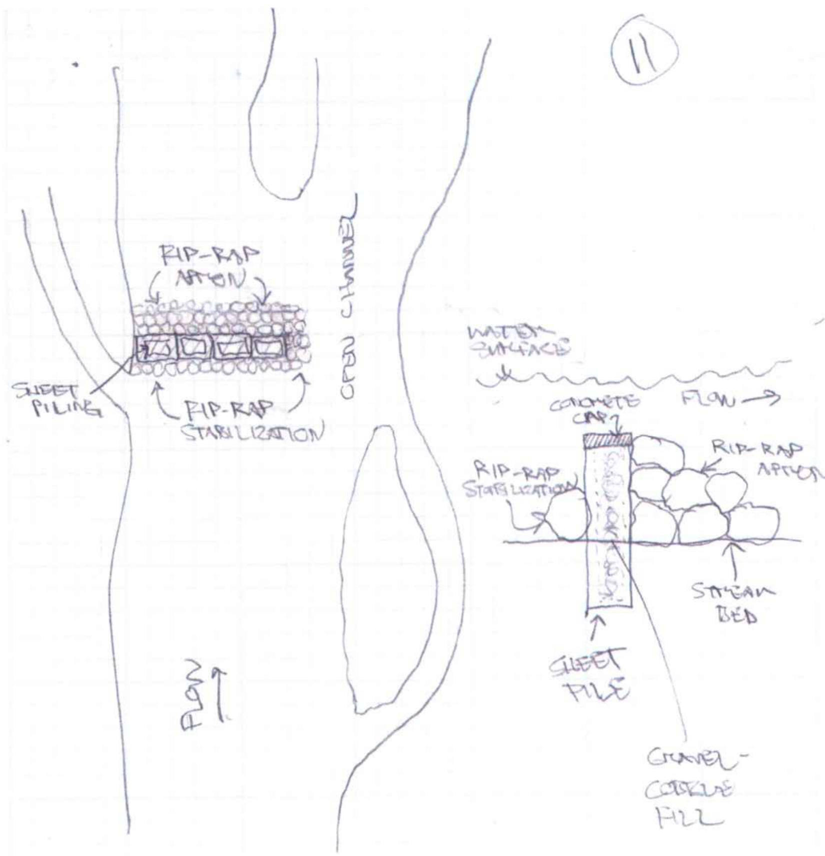

Figure 4-4 Partial Diversion Dam

Advantages:

- High likelihood of achieving intended purpose of year-round passage for all fish species because it more closely approximates an open channel.
- High likelihood of providing passage for “design” species (shovelnose sturgeon)
- Alternative will enhance recreation by providing boat passage
- Alternative may reduce entrainment of attracting fish
- Has advantage of being able to construct without dewatering

This alternative was dismissed from further consideration due to the following:

- Channel may change – physical modeling would be required to address post-construction effects

- More force will occur on a partial dam than a similarly constructed full width structure – design should consider and plan for no O&M for 30+ years following construction
- There may be some flow conditions that result in loss of head with some design configurations – physical modeling would be needed to optimize structure and minimize this risk
- Some bank stabilization may be required along island and south bank

4.4 Island – South Channel Passage

This alternative would open the south channel to fish passage by connecting the east end of the island to the existing dam, and removing a section of the dam at the southern terminus, to allow a natural gradient channel through that area.

As shown on Figure 4-5, a natural channel exists to the south of a large, well-established island that extends approximately 2,000 feet upstream from the dam. The channel is capped with cobble and gravel riffles at either end, and a deep slow moving portion through the remainder with gravel / fines / mud substrates. Lateral channel migration is prohibited by a large earthen dike to the south and the island bank to the north.

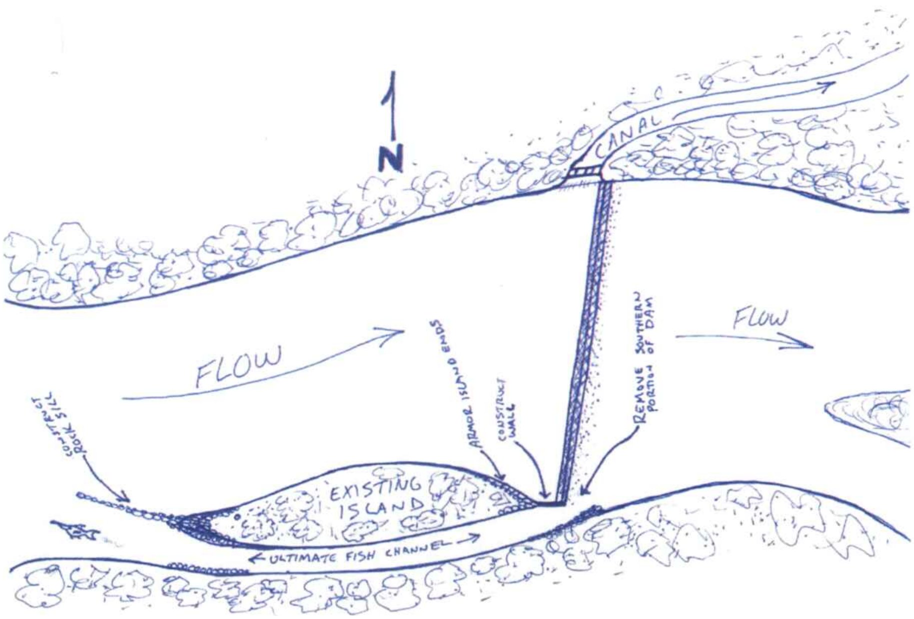

Figure 4-5 Island – South Channel Passage

This alternative would remove a southern portion of the dam comparable in width to the existing south channel. The dam would be removed down to the elevation of the current stream-bottom depth on the downstream side, therefore leaving the foundation portion of the dam as a grade control and erosion prevention structure. A deep pool exists immediately upstream from the dam in the short distance from the riffle to the dam. This pool would be filled to the level of the dam foundation and downstream stream bottom as well to prevent formation of deep plunge pool which may prohibit sturgeon and other less capable swimmers from accessing the channel. The remaining dam foundation would be armored on either side to prevent scour of the river bottom and erosion/loss of foundation.

A concrete wall would be built extending from the eastern tip of the island to the existing dam at or near its southern terminus. This wall should be higher than the water surface and current dam height to prevent overflow and scour of the new passage channel.

Low flow (attraction flow as well as passage flow over existing riffles) may be the limiting factor for this alternative. To assure adequate flow, we would extend a sill from upstream (western) tip of island essentially parallel to river flow. The sill would be low elevation. Riprap or hardening of upstream and downstream ends of the island may be necessary as well to prevent erosion.

<u>Advantages</u>:

- Provides passage to all fish species at all ages
- Provides fish passage by taking advantage of existing natural channel while maintaining current diversion capabilities.
- Recreational opportunities should not be lost with this option; boat and small vessel (kayak, canoe, tubes) passage will be enhanced.

This alternative was dismissed from further consideration due to the following:

- Less accessibility for O&M.
- Concern about low flow conditions and whether irrigation ditch will still be able to receive adequate flow.
- Risk of capture by channel by river, which could threaten the dike, the park, or even the community.

4.5 Raceway Notch Fish Passage

This alternative includes a passage channel through the dam with continuous gradient that meets minimum swim criteria and allows control of flow through the notch (Figure 4-6). The design configuration would be done to absorb energy and maintain head under most flow conditions.

- Channel will operate with a raceway shaped baffle on the upstream side.
- Under very low flows the notch can be closed to maintain head.
- Will require a reconfiguration of the dam plan view to help attract fish.
- Would require construction of road access on north side.
- Could require extra design to improve drowning safety.

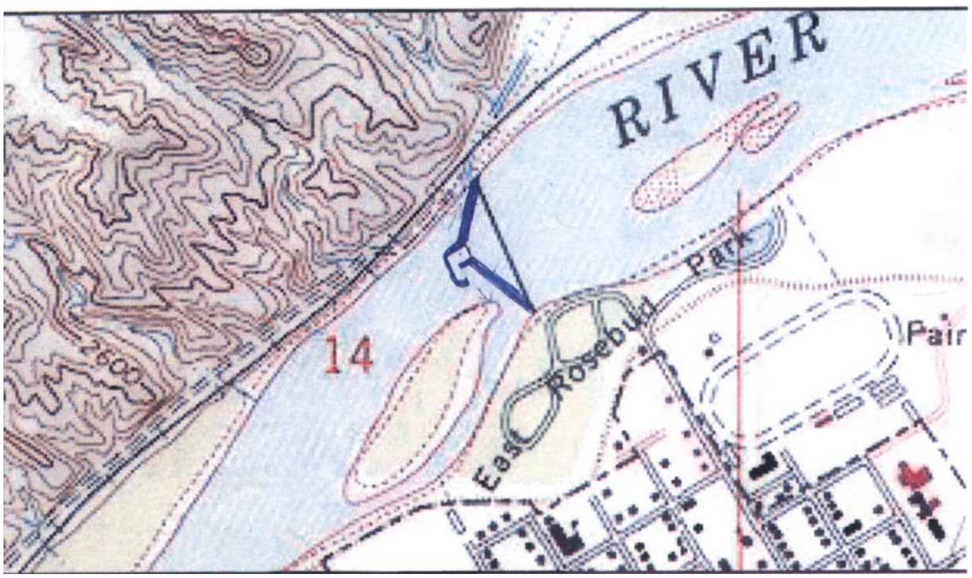

Figure 4-6 Raceway Notch Fish Passage

<u>Advantages</u>:

- Flows can be totally arrested by incorporating ability to dam notch channel
- Overall update to structure through reconstruction of dam
- Fish would be in main channel, would not have to navigate an artificial structure
- Would be designed not to change the head vis-à-vis city water intake

This alternative was dismissed from further consideration due to the following:

- Risk of loss of head
- Fish could be directed toward headgates.

- There could be loss of fish passage if damming of notch is necessary.
- May cause ice problems to island and park on one side and headworks on other
- Reconfiguring dam could require recreational facilities to be moved.
- Would have to evaluate sediment transport and effect on downstream geomorphology.
- Notch structure could be a sediment trap.

Unknowns: necessary velocity to meet swim criteria, width of channel to control velocity, and bathymetry

4.6 Rock Ramp (Preferred Alternative, February 2009 Study)

Under this alternative, the streambed would be reconfigured through either a U-shaped configuration (Figure 4-7) or a boulder weir (Figure 4-8) to reduce the channel gradient downstream from the existing diversion dam, allowing for fish movement upstream of the dam. The rock ramp would be designed to lower velocities and turbulence, so that migrating fish could easily make their way past the dam.

4.6.1 Streambed Reconfiguration (Boulder Weir)

The boulder weir design is used quite extensively in Europe, and has also been successfully implemented to pass lake sturgeon in Minnesota and Wisconsin. The design uses a 3% slope and 1-ft drops between the boulder weirs. To be conservative, since lake sturgeon could be stronger swimmers, the proposed conceptual design uses 1% slope with 0.5-ft drop between weirs, resulting in a structure with 16 boulder rows, 25-ft between rows, and 400-ft long. If a less conservative design is used (e.g. 2% slope) half the number of weirs (8) and half the length (200-ft) would be required.

Advantages of the boulder weirs:

- Provides a variety of velocities to pass all sizes and species of fish.
- The half circle configuration of boulders results in focusing low flow into the center during high flow conditions, lower fish friendly flows are along the sides.
- Use of boulders minimizes the amount of “fill” placed in the river.
- Boulders would be sized to resist ice (4-5 ft).

Figure 4-7 U-Shaped Rock Ramp

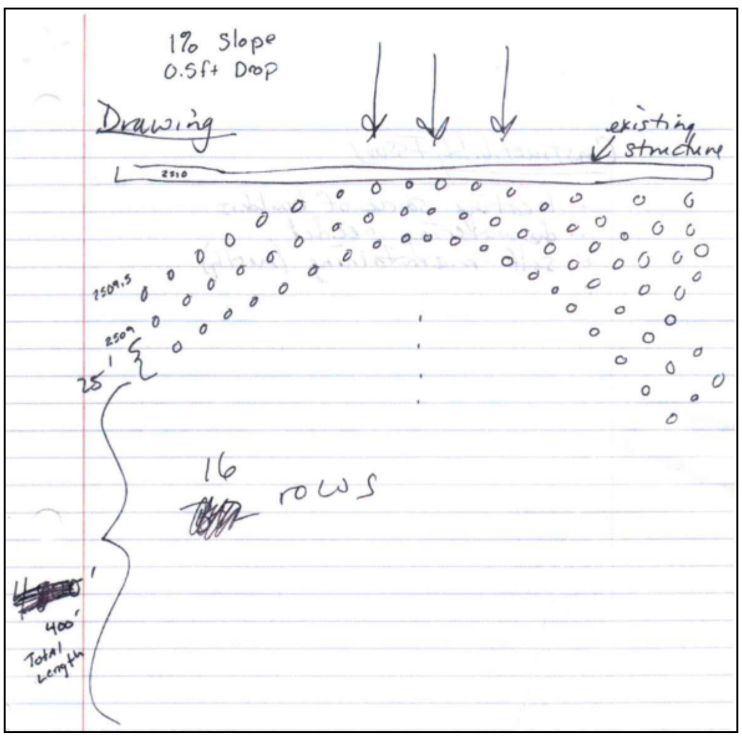

Figure 4-8 Boulder Weir

4.6.2 Streambed Reconfiguration (U-Shaped)

A modification to the streambed reconfiguration using boulder weirs is to construct a rock ramp utilizing an inverted "U" configuration to re-grade the river to the current crest height. The center of the "U" would be constructed at a 0.3% slope and the edges would be at 0.15% slope.

Advantages of the smooth inverted "U" rock ramp:

- Facilitates maintaining thalweg at engineered location
- Provides a variety of velocity diversity throughout structure
- Maintains or improves diversion stability (need to rebuild dam)
- Eliminates undertow factor (public safety)
- Makes dam passable by boat
- Provides passage for a variety of species year-round

4.7 Summary of Alternatives Comparison

The following matrices summarize how each alternative was measured against the screening criteria used during the alternatives analysis (Figures 4-9 and 4-10). The study participants prioritized the top four alternatives as follows:

- Streambed reconfiguration (U-shaped)
- Boulder weir
- Controlled notch
- Bypass channel

The Cartersville Irrigation District supported the first three alternative choices. The first two are variations of a rock ramp. The rock ramp alternative, with several options, and the controlled notch (inflatable bladder) will be further addressed in this document. Inflatable bladder options may consider widening the bladder up to full width of the dam.

ALTERNATIVE/ DESCRIPTION / FACTOR	DO NOTHING	PF 2&6	PF 9, 10, 12, AND 32	PF 9, 10, 12, AND 32	PF 11	PF 30	PF 40	PF 42
	EXISTING CONDITIONS	BYPASS CHANNEL; CIRCUMVENT OBSTRUCTIONS	STREAM BED RECONFIGURATION (BOULDER WEIR)	STREAM BED RECONFIGURATION (U-SHAPED)	PARTIAL DIVERSION DAM	ISLAND & SOUTH CHANNEL (DRAWING A).	NOTCH DAM	CONTROLLED NOTCH
CONSTRUCTIBILITY (BUILDABILITY, OPERABILITY, AND MAINTAINABILITY)	EASIER THAN AVERAGE	EASIER THAN AVERAGE	HARDER THAN AVERAGE	AVERAGE	HARDER THAN AVERAGE	HARDER THAN AVERAGE	HARDER THAN AVERAGE	HARDER THAN AVERAGE
ABILITY TO RELIABLY CONVEY WATER	BASELINE	LESS THAN BASELINE	EQUAL TO BASELINE	EQUAL TO BASELINE	LESS THAN BASELINE	LESS THAN BASELINE	EQUAL TO BASELINE	EQUAL TO BASELINE
ABILITY TO PROVIDE UPSTREAM PASSAGE FOR FISH	BASELINE	SLIGHTLY BETTER THAN BASELINE	BETTER THAN BASELINE	SIGNIFICANTLY BETTER THAN BASELINE	BEST	SLIGHTLY BETTER THAN BASELINE	BETTER THAN BASELINE	SLIGHTLY BETTER THAN BASELINE
LIKELY COMMUNITY ACCEPTANCE	NEUTRAL	MODERATE RESISTANCE	MODERATE RESISTANCE	MODERATE RESISTANCE	SIGNIFICANT RESISTANCE	MODERATE RESISTANCE	SLIGHT RESISTANCE	NEUTRAL
LIFE SPAN (50 TO 100 YEARS)	50	50	50+	50+	100	50	100	100
RECREATION	BASELINE	SOMEWHAT LESS OPPORTUNITY	DIMINISHED OPPORTUNITY	SOMEWHAT IMPROVED OPPORTUNITY	SOMEWHAT IMPROVED OPPORTUNITY	SOMEWHAT IMPROVED OPPORTUNITY	EQUAL TO BASELINE	SOMEWHAT IMPROVED OPPORTUNITY
POTENTIAL FLOOD PLAIN IMPACTS	BASELINE	EQUAL TO BASELINE	SLIGHT NEGATIVE IMPACT	SLIGHT NEGATIVE IMPACT	SLIGHT NEGATIVE IMPACT	SLIGHT NEGATIVE IMPACT	EQUAL TO BASELINE	SLIGHT POSITIVE IMPACT
REDUCE DROWNING RISK	BASELINE	EQUAL TO BASELINE	POSITIVE IMPACT	POSITIVE IMPACT	SLIGHT POSITIVE IMPACT	EQUAL TO BASELINE	EQUAL TO BASELINE	EQUAL TO BASELINE
COST		3	1	2	1	3	1	2

Figure 4-9 Summary of Alternatives, February 2009

	PF 2&6	PF 9, 10, 12, AND 32	PF 9, 10, 12, AND 32	PF 11	PF 30	PF 40	PF 42
	BYPASS CHANNEL; CIRCUMVENT OBSTRUCTIONS	STREAM BED RECONFIGURATION (BOULDER WEIR)	STREAM BED RECONFIGURATION (U-SHAPED)	PARTIAL DIVERSION DAM	ISLAND & SOUTH CHANNEL (DRAWING A).	NOTCH DAM	CONTROLLED NOTCH
First	1	1	16	4	0	0	0
Second	1	9	1	2	3	2	5
Third	3	3	1	0	5	4	6
Fourth	7	2	0	2	5	3	2
Fifth	2	1	0	4	2	4	0
Sixth	1	2	0	1	0	1	4
Seventh	2	0	0	2	0	2	0
Total Votes	**17**	**18**	**18**	**15**	**15**	**16**	**17**

Figure 4-10 Summary of Participant Rankings, February 2009